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ABSTRACT

The Eisenhower National Clearinghouse has prepared a series of publications, entitled A Perspective on Reform in Mathematics and Science Education, to support national reform efforts to improve teaching and learning in mathematics and science. This publication, Monograph #2 in the series, focuses on the activities of the American Association for the Advancement of Science through its visionary reform effort and landmark venture, Project 2061, and its publication of the two standards documents, "Science for All Americans" and "Benchmarks for Science Literacy." Monograph #2 is divided into three main sections: (1) "History of Project 2061"; (2) "Project 2061 Today"; and (3) "Plans for the Future." The major theme underlying the work of Project 2061 is that "...the education system should be reformed so that all American high school graduates are science literate." How the project began, what it means to be science literate, how this literacy will be achieved, and why it is necessary are described, as well as the next steps for Project 2061, and its potential contribution to national efforts to strengthen science education. (MKR)

ED 393 670

A Perspective on Reform in Mathematics and Science Education

Project 2061

for

The Eisenhower National Clearinghouse for Mathematics and Science Education

Monograph #2

Project 2061
American Association for the Advancement of Science

NCTM

National Science Teachers Association

Eisenhower National Clearinghouse for Mathematics and Science Education

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Neither the Eisenhower National Clearinghouse for Mathematics and Science Education nor the U.S. Department of Education is endorsing one reform approach over another—the series is distributed as a public service.

A Perspective on Reform in Mathematics and Science Education

by

Project 2061

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for

The Eisenhower National Clearinghouse for Mathematics and Science Education

Monograph #2

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Foreword

A major goal of the Eisenhower National Clearinghouse for Mathematics and Science Education (ENC) is to support national reform efforts to improve teaching and learning in mathematics and science. Integral to these efforts is the leadership of the American Association for the Advancement of Science (AAAS), the National Council of Teachers of Mathematics, and the National Science Teachers Association in developing and promoting these reforms. In cooperation with these organizations, the Clearinghouse has prepared a series of publications, each entitled *A Perspective on Reform in Mathematics and Science Education*.

This publication, Monograph #2, in the series, focuses on the activities of AAAS through its visionary reform effort and landmark venture, Project 2061. The major theme underlying their work in Project 2061 is that "...the education system should be reformed so that all American high school graduates are science literate." How the project began, what it means to be science literate, how this literacy will be achieved, and why it is necessary are clearly described in this publication. The next steps for Project 2061 and its potential contribution to national efforts to strengthen science education are also outlined.

ENC is pleased to have collaborated with AAAS in producing this publication. We believe reform efforts are crucial to achieving the National Education Goal 5, "By the Year 2000, U.S. students will be first in the world in mathematics and science achievement," and we believe cooperation among the organizations reaching for that goal is imperative. We want to thank Ann Cwiklinski, Project 2061, and thank the Communications staff at Aspen Systems Corporation who were responsible for the production of this publication.

Dr. Len Simutis, Director
Eisenhower National Clearinghouse

Invitation to Teachers

an you say that all the students in your district will someday graduate from high school literate in science, mathematics, and technology—that they will possess the knowledge and skills they need to make sense of how the world works, to think critically and independently, and to lead interesting, responsible, and productive lives in a culture that is increasingly reliant on science and technology? Many educators recognize that this is not the case for their students—at least not for all of them. And they know from experience that piecemeal changes to the curriculum are not the answer.

Project 2061's remedy calls for long-term reform of all aspects of K–12 education. Because teacher participation is critical to lasting system-wide change, Project 2061 is developing tools to support teachers and others involved with K–12 education in their local reform efforts. By identifying a common core of learning limited to the ideas and skills crucial to science literacy, we can help schools focus on what is essential to science literacy and teach it more effectively. By providing practical tools for educators to use in planning their own curriculum, we hope to foster local creativity and diverse instructional approaches.

We invite you to collaborate with Project 2061 in reforming K–12 science, mathematics, and technology education in this country so that high school graduates are truly science literate. We are eager to hear from teachers at all grade levels about how they are using Project 2061 tools in their school districts, and with what results.

Project 2061®
American Association for the Advancement of Science

What We Believe

roject 2061 believes that the education system should be reformed so that all American high school graduates are science literate. The conceptual basis for Project 2061 reform is explained in our 1989 report, *Science for All Americans (SFAA)*, which recommends what all students should know and be able to do in science, mathematics, and technology by the time they graduate from high school. *SFAA* is not a national curriculum, nor is Project 2061 seeking to produce a national curriculum. Rather, we are developing a set of tools to help school districts assemble their own curricula and promote science literacy among their students.

In addition to recommending specific understandings in a range of areas—the nature of science, mathematics, and technology; the physical setting; the living environment; the human organism; human society; the designed world; the mathematical world; historical perspectives; and common themes—*SFAA* describes habits of mind conducive to science literacy. These habits include both thinking skills and attitudes that enhance learning, such as curiosity, openness to new ideas, and skepticism. *SFAA* also enumerates principles that Project 2061 believes should guide teaching and learning for science literacy. *SFAA* goals are discussed in detail in the section Science for All Americans (see p. 6).

How does Project 2061 intend to foster science literacy across the country? A description of the Project's history and reform strategy follows below, but perhaps we should first sketch the general premises that guide our efforts to reform the education system:

■ Literacy in science, mathematics, and technology is important in helping people live interesting, responsible, and productive lives. In a culture increasingly pervaded by science, mathematics, and technology, science literacy requires understandings and habits of mind that enable citizens to grasp what those enterprises are up to, to make some sense of how the natural and designed worlds work, to think critically and independently, to recognize and weigh alternative explanations of events and design trade-offs, and to deal sensibly with problems that involve evidence, numbers, patterns, logical arguments, and uncertainties.

■ Reform must be comprehensive and long term. It must center on all children, all grades, and all subjects. It must extend to all aspects of the education system—curriculum, teacher education, the organization of instruction, assessment, materials and technology, policy, and more—all of which, we recognize, take time.

■ Curriculum reform should be shaped by a vision of the lasting knowledge and skills we want students to acquire by the time they become adults. This vision should include both a common core of learning—the explicit learning outcomes detailed in *Science for All Americans* and in our latest report, *Benchmarks for Science Literacy*—and learning that addresses the particular needs and interests of individual students.

■ If we want students to learn science, mathematics, and technology well, we must radically reduce the sheer amount of material now being covered. An overstuffed curriculum places a premium on the ability to commit terms, algorithms, and generalizations to short-term memory and impedes understanding. The common core of instruction should omit what does not contribute to science-literacy goals so that students have time to learn well what does.

■ The common core of learning in science, mathematics, and technology should center on science literacy, not on a disjointed understanding of the separate disciplines. Moreover, the core studies should include connections among science, mathematics, and technology and between those areas and the arts, humanities, and vocational subjects.

■ When designing a curriculum, learning goals should be stated so as to reveal the intended character and sophistication of learning to be sought. And although goals for knowing and doing can be described separately, we believe they should be learned together in many different contexts so that they can be used together in life outside school.

■ Common goals do not dictate uniform curricula, teaching methods, and materials—variety is important. Project 2061 is developing tools to enable teachers to design learning experiences that reflect State and district requirements, student backgrounds and interests, teacher preferences, and the local environment. Project 2061 reform strategy will lead eventually to greater curriculum diversity than is common today.

■ Promoting equity in science education is a priority. Students should be served equally well in the light of their various circumstances and needs. Race, ethnicity, culture, gender, economic circumstances, physical limitations, and location should be considered when designing and implementing a curriculum—however, these factors should never be used as excuses for some students to receive a worse education than others.

History of Project 2061

Project 2061's reform strategy involved first outlining goals for student learning nationwide and then creating tools to help educators design curricula to meet those goals in their own districts.

Establishing Goals

In 1985, after 3 years of planning, the American Association for the Advancement of Science (AAAS), the world's largest federation of science and engineering societies, launched a long-term, comprehensive project to radically improve science, mathematics, and technology education for the 21st century. The 1985 approach of Halley's Comet prompted the project's originators to muse on all the scientific and technological changes that a child entering school in 1985 would live to witness before the return of the Comet in 2061—hence the name, Project 2061.

Project 2061 began with a five-person staff that has since grown to more than 20 individuals, assisted by dozens of consultants. From the beginning, the Project has been advised by the National Council on Science and Technology Education—successive advisory boards composed of about 30 concerned scientists, mathematicians, engineers, business leaders, state legislators, governors, school board members, parents, and classroom teachers from across the country. The Council guides and supports the reform efforts of Project 2061, contributing to our national perspective.

Panel Reports

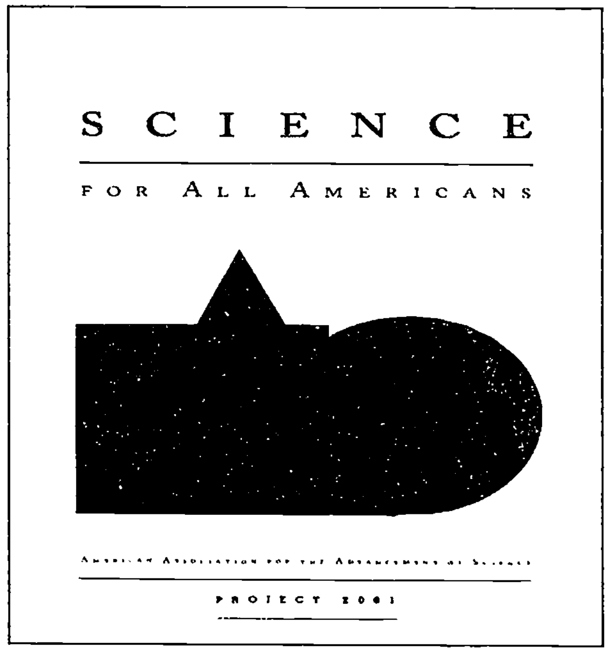
We wanted people with considerable knowledge about some branch of science, mathematics, or technology to help us define science literacy. In 1985, Project 2061 engaged five panels of scientists, mathematicians, and engineers to recommend learning goals for all American high school graduates. Each panel, located in a different part of the country, was composed of professionals who were accomplished in their fields, open to new ideas, and thoughtful about the roles of science, mathematics, and technology in the lives of Americans. While diverse demographically, professionally, and educationally, these individuals had in common a willingness to explore the question: "Out of all possibilities, what knowledge, skills, and ways of thinking should everyone derive from science, mathematics, and technology by the time they complete high school?" Members of each panel were close enough together to meet often to identify and discuss with their colleagues the ideas essential to science literacy.

The panels fell under five broad groupings: biological and health sciences; social and behavioral sciences; physical and information sciences and engineering; mathematics; and technology. For about 2 years the panels met periodically to present ideas to each other, to discuss and argue about these ideas, and to confer with consultants or members of the other panels. Each group developed working papers, invited criticism, and reworked their ideas accordingly. Their recommendations appeared in five panel reports, which were published separately as well as integrated in the Project's 1989 report, *Science for All Americans*.

Science for All Americans

Science for All Americans, the keystone of our effort, recommends and defines a coherent set of learning goals for high school graduates, providing educators with a shared sense of the direction that science, mathematics, and technology education should follow in this country.

The recommendations in *SFAA* for the content of a core curriculum can be summarized in four general categories: the scientific endeavor, scientific views of the world, perspectives on science, and scientific habits of mind. *SFAA* also



presents principles that Project 2061 believes should guide teaching and learning for science literacy; these appear in *SFAA*'s Chapter 13, Principles of Effective Learning and Teaching.

The Scientific Endeavor. All students should leave school with an awareness of what the scientific endeavor is and how it relates to their culture and to their lives. This awareness should include an understanding of the following concepts:

■ The scientific endeavor draws on science, mathematics, and technology. Technology provides science and mathematics with tools and techniques that are essential for inquiry and often suggests new avenues of investigation. In the past, new technologies were based on accumulated practical knowledge; today they are more often based on a scientific understanding of the principles that underlie how things behave. Mathematics itself is a science; however, it also provides the chief language of the natural sciences and a powerful analytical tool widely used in both science and technology.

■ Science, mathematics, and technology have roots going far back into history and into every part of the world. Just as all peoples have been inventive, shaping tools and developing techniques for modifying their environment, so too have they been curious about nature and how it works. Although modern science—which is truly international—is only a few centuries old, aspects of it (especially in mathematics and astronomy) can be traced back to the early Egyptian, Greek, Chinese, and Arabic cultures.

■ Science, mathematics, and technology are expressions of both human ingenuity and human limitations, with intellectual, practical, emotional, esthetic, and ethical dimensions. Progress in these fields results from the cumulative efforts of human beings with diverse interests, talents, and personalities, although social barriers have led to the underrepresentation of women and minorities.

■ The various natural and social sciences differ from each other somewhat in subject matter and technique, yet they share certain values, philosophical views about knowledge, and ways of learning about the world. All of the sciences presume that objects and events in the universe occur in consistent patterns that are comprehensible through careful and systematic study. Although all the sciences aim to produce verifiable knowledge, none claims to produce knowledge that is absolutely true and beyond change.

■ The subject matter investigated and techniques used within the various sciences change with time and the development of new instruments, and the boundaries of the scientific disciplines are constantly shifting. Even so, the general attributes of scientific inquiry persist. Descriptive, experimental, and historical approaches are used, depending on the phenomena being studied and the tools at hand. However, the approaches are all alike in their demand for evidence, their use of testable hypotheses and logical reasoning, their search for explanatory and predictive theories, and their efforts to identify and avoid bias.

■ Mathematics is the science of abstract patterns and relationships. As a theoretical discipline, it explores the possible relationships among abstractions without concern for wheth they have counterparts in the real world. It often turns out, however, that discoveries in pure mathematics have surprising and altogether unanticipated practical value. As an applied science, mathematics deals with problems that originate in the natural and social sciences and in the everyday world of experience. In trying to solve such problems, it sometimes happens that fundamental mathematical discoveries are made.

■ Whether theoretical or applied, mathematics is a creative process rather than one of using memorized rules to calculate answers. Mathematical processes include representing some aspects of things abstractly, manipulating the abstractions logically to find new relationships between and among them, and seeing whether the new relationships say something useful about the original things. The things studied in this way may be objects, collections, events, processes, ideas, numbers, or other mathematical abstractions.

■ In the broadest sense, technology extends our abilities to change the world: to cut, shape, or put together materials; to move things from one place to another; and to reach farther with our hands, voices, senses, and minds. Engineering is a process of designing and building technological systems to achieve such changes. Engineers must consider physical, economic, political, social, ecological, esthetic, and ethical factors, and make trade offs among them.

■ Technological and social systems strongly interact with each other. Social and economic forces determine which technologies will be undertaken, paid attention to, invested in, and used; technology, in turn, has always had an enormous impact on the nature of human society. Some of the social effects of technological change—benefits, costs, and risks—can be anticipated, while others cannot.

Scientific Views of the World. Knowledge of science, mathematics, and technology is valuable because it makes the world more comprehensible and more interesting. *Science for All Americans* does not advocate, however, that all students need to gain detailed knowledge of the scientific disciplines as such. Instead, the report recommends that students develop a set of cogent views of the world as illuminated by the concepts and principles of science. Such views include the following:

■ The structure and evolution of the universe, with emphasis on the similarity of materials and forces found within it, how the universe displays general principles (such as universal gravitation and the conservation of energy), and ways in which the universe is investigated.

■ The general features of the planet Earth, including its location, motion, origin, and resources; the dynamics by which its surface is shaped and reshaped; the effect of living organisms on its surface and atmosphere; and how its landforms, oceans and rivers, climate, and resources have influenced where and how people live and how human history has unfolded.

■ The basic concepts related to matter, energy, force, and motion, with emphasis on their uses in models to explain a vast and diverse array of natural phenomena from the birth of stars to the behavior of cells.

■ The living environment, emphasizing the rich diversity of the Earth's organisms and the surprising similarity in the structure and functions of their cells; the dependence of species on each other and on the physical environment; and the flow of matter and energy through the cycles of life.

■ Biological evolution as a concept based on extensive geological and molecular evidence, as an explanation for the diversity and similarity of life forms, and as a central organizing principle for all of biology.

■ The human organism as a biological, social, and technological species—including its similarities to other organisms, its unique capacity for learning, and the strong biological similarity among all humans in contrast to the large cultural differences among groups of them.

■ The human life cycle through all stages of development and maturation, emphasizing factors that contribute to the birth of a healthy child, to the fullest development of human potential, and to improved life expectancy.

■ The basic structure and functioning of the human body, seen as a complex system of cells and organs that serve the fundamental functions of deriving energy from food, protection against injury, internal coordination, and reproduction.

■ Physical and mental health as they involve the interaction of biological, physiological, psychological, social, economic, cultural, and environmental factors, including the effects of food, exercise, drugs, and air and water quality.

■ Features of human social dynamics, including the consequences of the cultural setting into which a person is born, the nature and effects of class distinctions, the variations among societies in what is considered appropriate behavior, the social effects of group affiliation, and the role of technology in shaping social behavior.

■ Social change and conflict, with emphasis on factors that stimulate or retard change, the significance of social trade offs, causes of conflict, mechanisms for resolving conflict among groups and individuals, the role of governments in directing and moderating change, and the effects of the growing interdependence of world social and economic systems.

■ Forms of political and economic organization, emphasizing the intertwining of political and economic viewpoints, the ways in which theoretical political and economic systems differ, and the frequent mixing of capitalistic and socialistic systems in practice.

■ The human population, including its size, density, and distribution; the technological factors that have led to its rapid increase and dominance; its impact on other species and the environment; and its future in relation to resources and their uses.

■ The nature of technologies, including agriculture, with emphasis on both the agricultural revolution in ancient times and the effects of the use of biological and chemical technologies on 20th-century agricultural productivity; the acquisition, processing, and use of materials and energy, with particular attention to both the Industrial Revolution and the current revolution in manufacturing based on the use of computers; and information processing and communications, with emphasis on the impact of computers and electronic communications on contemporary society.

■ Medical technologies, including mechanical, chemical, electronic, biological, and genetic materials and techniques; their use in enhancing the functioning of the human body; their role in the detection, diagnosis, monitoring, and treatment of disease; and the ethical and economic issues raised by their uses.

■ The mathematics of symbols and symbolic relationships, emphasizing the kinds, properties, and uses of numbers and shapes; graphic and algebraic ways of expressing relationships among things; and coordinate systems as a means of relating numbers to geometry and geography.

■ Probability, including the kinds of uncertainty that limit knowledge, methods of estimating and expressing probabilities, and the use of such methods in predicting results when large numbers are involved.

■ Data analysis, with an emphasis on numerical and graphic ways of summarizing data, the nature and limitations of correlations, and the problem of sampling in data collection.

■ Reasoning, including the nature and limitations of deductive logic, the uses and dangers of generalizing from a limited number of experiences, and reasoning by analogy.

Perspectives on Science. Science literacy also includes seeing the scientific endeavor in the light of cultural and intellectual history and being familiar with powerful ideas that cut across the landscape of science, mathematics, and technology. To that end, *SFAA* recommends that all students develop the following perspectives on science:

■ An awareness that scientific views of the world result both from a combination of evolutionary changes, consisting of many small discoveries accumulating over long periods of time, and from revolutionary changes, consisting of the rapid reorganization of ways of thinking about the world.

■ Familiarity with episodes in the history of science and technology that are of surpassing significance for our cultural heritage. Such milestones in the development of Western thought and action include Galileo's role in changing our perception of our place in the universe; Newton's demonstration that the same laws apply to motion in the heavens as on the Earth; Darwin's observations of the variety and relatedness of life forms that led to his postulating a mechanism for how they came about; Lyell's inference of the great age of the Earth from layers of rock; and Pasteur's identification of infectious disease with tiny organisms that could be seen only with a microscope.

■ An understanding of thematic ideas that have proven to be especially useful in thinking about how things work. These include the idea of systems as a unified whole in which each part is understandable only in relation to the other parts; of models as physical devices, drawings, equations, computer programs, or mental images that suggest how things work or might work; of stability and change in systems; and of the effects of scale on the behavior of objects and systems.

Scientific Habits of Mind. Throughout history, people have concerned themselves with the transmission of habits of mind—shared values, attitudes, and ways of thinking—from one generation to the next. Given the great and increasing impact of science and technology on every facet of contemporary life, part of science literacy consists of possessing certain scientific values, attitudes, and patterns of thought. Accordingly, *SFAA* recommends that elementary and secondary education be modified as necessary to ensure that all students emerge with the following:

■ The internalization of values inherent in the practice of science, mathematics, and technology, especially respect for the use of evidence and logical reasoning in making arguments; honesty, curiosity, and openness to new ideas; and skepticism in evaluating claims and arguments.

■ Informed, balanced beliefs about the social benefits of the scientific endeavor—beliefs based on the ways in which people use knowledge and technologies and also on the continuing need to develop new knowledge and technologies.

■ A positive attitude toward being able to understand science and mathematics, deal with quantitative matters, think critically, measure accurately, and use ordinary tools and instruments (including calculators and computers).

■ Computational skills, including the ability to make certain mental calculations rapidly and accurately; to perform calculations using paper and pencil and electronic calculators; and to estimate approximate answers when appropriate and to check on the reasonableness of other computations.

■ Manipulation and observation skills, with emphasis on the correct use of measuring instruments; the ability to use a computer for storing and retrieving information; and the use of ordinary hand tools.

■ Communication skills, including the ability to express basic ideas, instructions, and information clearly both orally and in writing, to organize information in tables and simple graphs, and to draw rough diagrams. Communicating effectively also includes the ability to read and comprehend science and technology news as presented in the popular print and broadcast media, as well as general reading skills.

■ Critical-response skills that prepare people to carefully judge assertions—especially those that invoke the mantle of science—made by advertisers, public figures, organizations, and the entertainment and news media, and to subject their own claims to the same kind of scrutiny so as to become less bound by prejudice and rationalization.

Principles of Effective Learning and Teaching (SFAA's Chapter 13). Even a sampling of the principles presented in this chapter suggests something of the radical transformation Project 2061 is looking for in the schools:

■ Learning experiences should foster both scientific knowledge of the world and scientific habits of mind. Students should acquire the habit of questioning evidence, logic, and claims. They should encounter problems that require them to identify relevant evidence and offer their own interpretations of what the evidence means.

■ Science teaching should foster and build on students' curiosity and creativity. Teaching should begin with questions and phenon.ena that are interesting and familiar to students. Instruction should emphasize the quality of understanding rather than the quantity of information. Technical vocabulary should be stressed only insofar as it contributes to understanding—and never prematurely.

■ Concepts are learned best when they are encountered in a variety of contexts and expressed in a variety of ways. Some concepts will be learned only when students restructure their thinking radically. Abstract understanding often has to be built upon concrete examples in the context of some relevant conceptual structure.

■ If students are ultimately expected to apply ideas in novel situations, think critically, analyze information, communicate scientific ideas, make logical arguments, and work as part of a team, they must have opportunities to practice doing so in many contexts. Students also need many and varied opportunities to engage in the activities associated with science—such as collecting, observing, sketching, interviewing, and using common instruments, in particular those for measuring. The collaborative nature of scientific and technological work should be reflected in the classroom by fr quent group activity.

■ Students should encounter many scientific ideas presented in historical context. They should become aware of the influence of society on the development of science and technology, and the impact of science and technology on society.

We recognize that these are not practices that can be easily spliced into the existing science curriculum. Our suggestions for teaching and learning imply radical changes in the way school time is organized. We are suggesting that students need time for exploring, for making observations, for taking wrong turns, for testing ideas, for doing things over again; time for building things, calibrating instruments, collecting things, constructing physical and mathematical models for testing ideas; time for learning whatever mathematics, technology, and science they may need to deal with the questions at hand; time for asking around, reading, and arguing; and time for wrestling with unfamiliar and counterintuitive ideas and for coming to see the advantage of thinking in a different way.

Using *Science for All Americans*

In addition to informing the development of further Project 2061 reform tools, *SFAA* has been put to use by educators across the country. More than 100,000 copies of *SFAA* are now in circulation. School districts, large and small, urban and rural, are using *SFAA* as a guide for their own curriculum reform activities. Although Project 2061 has not been actively promoting such undertakings—we believe we can best serve local curriculum reform by developing the rest of our curriculum design tools—we often hear from educators that they have been using *SFAA* to develop curricula, or consulting *SFAA*'s principles of effective learning and teaching to stimulate thought and discussion about classroom changes such as:

- Finding out how students already think about every major topic in *SFAA*.
- Giving students enough evidence and time to actually change any misconceptions.
- Increasing the use of team approaches that allow more active participation by each student.
- Shifting classwork toward ideas and thinking and away from vocabulary and predetermined answers.
- Making sure that girls, minorities, and the disabled are fully engaged in all class activities in science, mathematics, and technology.
- Expecting and rewarding clear and accurate reports, both written and oral, of students' thinking and activities.

Developing Reform Tools

With *SFAA*, the Project set learning goals in science, mathematics, and technology for all high school graduates. However, setting goals was only the first step towards effecting real change. A curriculum designer or teacher for the early grades would be hard put to make decisions about 2nd-grade curriculum based on *SFAA* alone. And even for the later grades, *SFAA* includes virtually no recommendations about the sequence of instruction, techniques for teaching specific content, or suggestions for materials and tests. The task remained to translate the ideas of *SFAA* into practical guidelines that school districts nationwide could adopt in creating their own K–12 curricula. We recognized that any successful reform strategy would have to consider that the level and nature of participation in curriculum reform varies across school districts. In some school districts, teachers and administrators expect to play a major role in actually designing whatever curriculum will be introduced; in other districts, they prefer to adopt a ready-made curriculum, concentrating on implementation rather than design. And perhaps the teachers in most schools are somewhere in between: they like to start with a well-defined curriculum framework that is not overly prescriptive, so that they can adapt it to their own circumstances and preferences. Project 2061 wanted to respond to this range of needs.

Immediately after the publication of *SFAA*, we turned to two interrelated tasks: (1) developing leaders among school teachers and administrators to actually carry out reform in their districts and engage their colleagues nationwide in similar efforts and (2) creating a flexible set of tools to help schools, districts, and States design their own curricula to meet the goals in *SFAA*.

School-District Teams

Who could best help us create curriculum design tools? Though scientists and engineers could provide us with important insights into their disciplines, and researchers in learning and education could supply us with valuable information about the struggle students have with difficult concepts, we wanted people with a clear sense of changes urgently needed in the classrooms to help us create practical tools for curriculum design. Project staff and consultants decided that if traditional constraints were removed and adequate time and resources were provided, teams of school teachers and administrators, backed by education specialists and scientists, would be able to help us develop curriculum design tools that would prove useful and credible to other teachers.

We knew the Project teams would have to be exceptional: ready to assume leadership in their districts; willing to take on risks; well versed in the major ideas of science, mathematics, and technology; possessed of a broad educational perspective, encompassing several disciplines and spanning the entire K–12 learning process; and experienced in designing curricula. Although this array of qualities was unlikely to be found in even the most outstanding team of teachers in a given district, it was certainly worth cultivating.

Rather than one centralized team, we wanted teams from several school districts across the country: we believed that conditions at a variety of sites could inspire the development of a range of alternative curriculum models that would suggest possibilities for mathematics, science, and technology curricula nationwide. So that the teams might collectively represent the demographics of the Nation, we sought to establish teams in urban, suburban, and rural school districts where ethnic minorities and other traditionally underserved groups were amply represented. Other important criteria in our selection of sites were the enthusiasm and talent of the local teachers and administrators, the commitment of the school district and community, and the support of a local university, preferably one strong in science, mathematics, engineering, education, cognitive science, and developmental psychology. We also wanted evidence that substantial thinking about reform was already underway at the site.

We were keen on getting several states involved with the Project, preferably states where the department of education demonstrated a commitment to overhauling the mathematics and science curriculum and held some sway over textbook publishing companies and test-making firms. California and Texas were considered as prospective participants early on and seemed amenable to the sort of radical reform suggested by Project 2061. We encouraged these states to actively support the Project by examining state guidelines for the curriculum in light of *SFAA* and collaborating with a local Project 2061 district team.

We eventually settled on six sites across the country that seemed likely to come up with powerful new curriculum ideas:

- Georgia: Two rural school districts (Elbert and Greene Counties) near Athens, Georgia. Backed by the University of Georgia at Athens.

- McFarland, Wisconsin: A small, suburban school district. Backed by the University of Wisconsin at Madison.

- Philadelphia, Pennsylvania: One of the largest school districts in the country, with 200,000 students, most of them African-American and Hispanic. Backed by the University of Pennsylvania, Drexel University, and numerous foundations, museums, cultural and scientific organizations, and corporations through the city's PATHS/PRISM program.

- San Antonio, Texas: Four independent school districts with a large inner-city Hispanic population. Backed by the University of Texas at San Antonio, Trinity University, and the University of Texas Health Science Center.

■ San Diego, California: A multicultural school district in urban/suburban San Diego. Backed by San Diego State University and the University of California at San Diego.

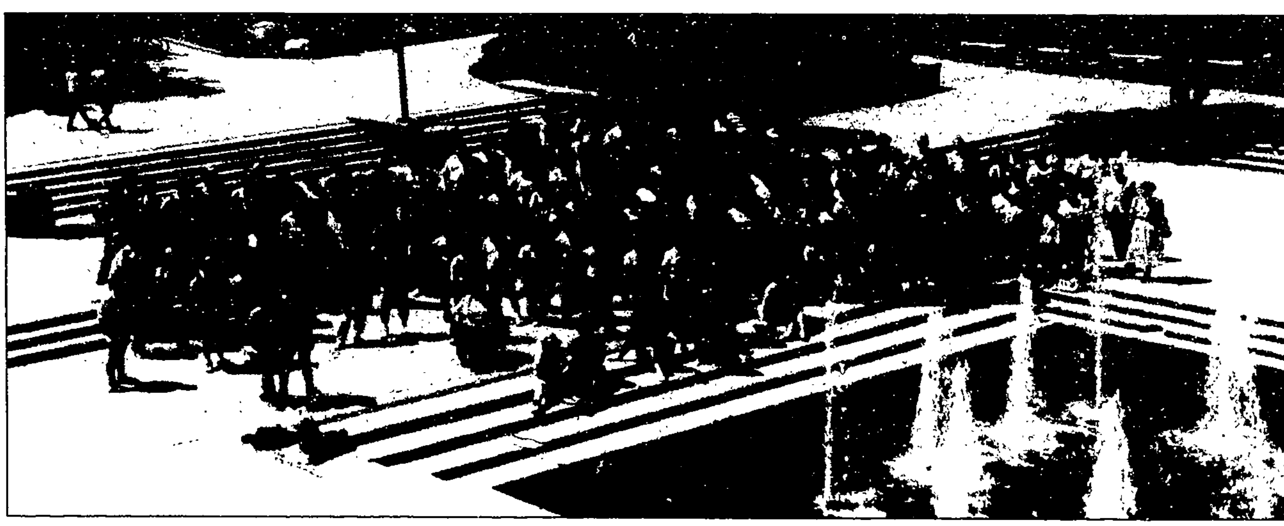
■ San Francisco, California: An inner-city school district with great ethnic diversity. Backed by the Lawrence Hall of Science at the University of California, Berkeley, and San Francisco State University.

With the help of the local school district community advisory committees, the Project enlisted a capable and committed team of 25 teachers and administrators at each of the six sites. So that they could plan for 13 years of schooling in science, mathematics, and technology, each team consisted of five elementary teachers, five middle school teachers, 10 high school teachers, one principal from each level, and two curriculum specialists—all from various disciplines, including the life and physical sciences, social studies, mathematics, technology, and the humanities.

printer, modem, and appropriate software. Some computers were connected to a local network, and the team leaders at the six sites were connected by network to each other and to Project 2061's AAAS headquarters.

The school districts agreed to release team members an average of 4 days per month from their classrooms to work on Project 2061 tasks. Faculty from local universities provided consultation and technical assistance to the teams upon request. Consultants across the country offered their expertise at annual summer conferences, where staff and teams met to advance mutual tasks.

All of the teams took some time becoming accustomed to working in cross-grade, cross-discipline groups, but the time was well spent, resulting in some novel approaches to curriculum design, as well as a core group of school-based educators who developed a rich understanding of science, mathematics, and technology and a broad educational perspective.



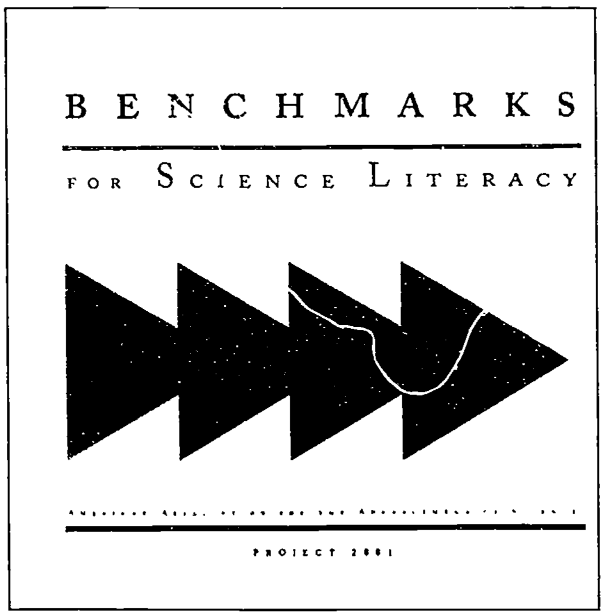
Project 2061 school-district teams at first summer conference; Boulder, Colorado, 1989.

AAAS and each local district arranged financial, academic, and practical support—including clerical help, office space, reference materials, travel funds, and other resources—that would enable the teams to produce the best curriculum products possible and to become local leaders of curriculum reform. IBM agreed to provide hardware, software, networking, and technical training and maintenance so that each site office and each team member had a computer,

The teams' work was enhanced by research on education and learning in science, mathematics, and technology; their own experiences with students; and discussions with Project 2061 staff, consultants, and each other. In addition to frequent meetings at their sites to work on their local models, the six teams and Project 2061 staff convened at universities for extended work sessions during the summers of 1989–1992. These sessions, held at the University of

Colorado in Boulder, the University of Wisconsin in Madison, the University of Washington in Seattle, and Cornell University in Ithaca, New York. allowed participants to discuss at length issues and strategies related to curriculum and reform.

Though their original assignment was, simply stated, to produce a curriculum model that would meet the goals in *SFAA*, their work evolved to include many different tasks related to designing curricula and implementing reform. The teams' important contributions over the past 6 years are described at greater length in the following sections on the development of specific reform tools.



Benchmarks for Science Literacy

Since the publication of *SFAA* in 1989, Project 2061 has been developing an array of curriculum-design tools to help school districts promote science literacy. The first of these was *Benchmarks for Science Literacy*, developed with considerable help from the Project's six school-district teams.

While working on their curriculum models, the team members had to confront the question of how to sequence student understanding from the rudimentary ideas that could be grasped by kindergartners toward the more sophisticated goals in *SFAA*. For 2 years, the teams worked independently to map out such sequences for many sections of *SFAA*, convinced that mapping stimulated the kind of thinking about sequence of instruction that was essential to the design of any sound K–12 curriculum model.

By 1991 Project staff and the site teams realized that a common set of expectations for students at various grade levels was needed. The individual teams believed that their progress on curriculum models was being delayed by the slow production—and, therefore, the shortage—of maps. The Project teams were finding a need for clear statements about learning goals to share with local colleagues who were developing curriculam. District pressure was mounting for teams to share their curriculum models so that Project 2061 ideas could find their way as soon as possible into classrooms. Also, while introducing Project 2061 to audiences at national and regional education conferences and seminars, staff and team members observed a growing demand for the maps themselves—educators wanted to adopt the maps for their own curriculum reform efforts.

Staff and teams agreed to derive from their maps a common set of expectations, or *Benchmarks*, for their own and public use. This set of *Benchmarks* would serve two purposes: (1) It would be a useful tool for educators faced with the task of designing a curriculum that helps students connect ideas over time and across disciplines, and (2) it would ensure that the alternative curriculum models designed by the teams and, in the future, by other curricular designers, would encourage the understandings and habits of mind described in *SFAA*. Though other education initiatives set standards at grades 4, 8, and 12, all of the Project teams independently concluded that the psychological difference between a kindergartner and a 4th grader was so significant that an earlier checkpoint was needed. They decided to set *Benchmarks* at the ends of grades 2, 5, 8, and 12.

Cooperative efforts to produce a comprehensive set of *Benchmarks* began with the teams sharing their lists and maps of grade-level expectations. By summer 1992, the Project's editorial review board—consisting of several staff members, representatives from each team. and consultants with expertise in analyzing how students' ideas develop over time—had developed lists of *Benchmarks* to correspond to most of the sections in *SFAA*. The *Benchmarks* in these lists were divided by the agreed-upon grade spans (K–2, 3–5, 6–8, and 9–12). In fall 1992, the board reviewed and improved the lists as much as possible, adding *Benchmarks* to meager early-grade lists, shifting *Benchmarks* based on research on children's learning capabilities, and ensuring that the more difficult benchmark concepts were anticipated sufficiently by *Benchmarks* at earlier grade spans. After considering what format would make the *Benchmarks* most accessible to curriculum designers, including teachers, the review board wrote helpful essays to accompany each list of *Benchmarks*. The essays clarify the benchmarks, suggesting such things as how one benchmark relates to others, what difficulties might interfere with student understanding, and how to overcome some of these difficulties. While suggesting some learning experiences to foster understanding, the essays are not intended to prescribe instruction.

The document underwent a comprehensive review by hundreds of elementary, middle, and high school teachers, as well as by administrators, scientists, mathematicians, engineers, historians, and experts on learning and curriculum design. Reviewers were asked to consider whether the science was correct, the grade placements reasonable, the language clear, and the format helpful for development of curriculum or instruction. The Project was particularly interested in group review, through which *Benchmarks* would be subject to discussion. Members from each of the Project 2061 teams conducted review sessions where participants could debate the strengths and weaknesses of the draft. In addition, more than 75 volunteer groups across the country responded to an invitation in the Project newsletter to review the document. Many of these volunteers, as it turns out, were educators revamping their district curricula. They were eager to influence a national project as well as get some good ideas for their own schools. Many indicated that the *Benchmarks* will directly influence their district or state curriculum guidelines.

Staff attended to more than 1,300 responses from individuals in 46 states and five countries. Urban and rural school districts and diverse disciplines were represented in the review. The resulting publication, *Benchmarks for Science Literacy*, serves as a companion to *SFAA*; together the two publications can help guide curriculum design and reform in science, mathematics, and technology education. By translating the literacy goals of *SFAA* into expectations for the end of grades 2, 5, 8, and 12, *Benchmarks* can help educators decide what content to include in (or exclude from) a core curriculum, what order to teach it in, and why.

Because *Benchmarks for Science Literacy* is a unique tool for curriculum design—in content, organization, and purpose—an accurate description depends on identifying what it is not, as much as identifying what it is:

■ ***Benchmarks* is different from a curriculum, a curriculum framework, a curriculum design, or a plan for a curriculum.** It is a tool to be used by educators in designing a curriculum that makes sense to them and that meets the goals for science literacy recommended in *SFAA*. Moreover, *Benchmarks* does not advocate any particular curriculum design. Far from pressing for one way of organizing instruction, Project 2061 pursues a reform strategy that will lead eventually to greater curriculum diversity than is common today.

■ ***Benchmarks* is a compendium of specific science-literacy goals that can be organized however one chooses.** As in most reference works, chapter order is unrelated to the relative importance of the *Benchmarks*. Chapter 1 does not set the tone for all successive chapters, nor does the final chapter culminate all that came before. Indeed, Project 2061 expects that curriculum units designed to address science-literacy goals will combine *Benchmarks* from Chapter 12, Habits of Mind, with *Benchmarks* from various other chapters. *Benchmarks on Disk* enables users to assemble *Benchmarks* from multiple chapters into cogent sets.

■ ***Benchmarks* specifies thresholds rather than average or advanced performance.** It describes levels of understanding and ability that all students are expected to reach on the way to becoming science literate. A well-designed curriculum will provide students with the help and encouragement they need to meet those goals.

■ ***Benchmarks* concentrates on the common core of learning that contributes to the science literacy of all students.** It does not spell out all science, mathematics, and technology goals that belong in the K–12 curriculum. Most students have interests, abilities, and ambitions that extend beyond the core studies, and some have learning difficulties that must be taken into account.

■ ***Benchmarks* avoids technical language used for its own sake.** The number of technical terms that most adults must understand is relatively small. Accordingly, the 12th-grade *Benchmarks* use only those technical terms that usually appear in the vocabularies of science-literate people. The language in the *Benchmarks* for earlier grades is intended to signal the nature and sophistication of understandings to be sought. Project 2061 analysis of these and other issues is summarized in *Benchmarks*' Chapter 14, Issues and Language.

■ ***Benchmarks* sheds only partial light on how to achieve the goals it recommends.** Deliberately. The means for realizing the ends listed in *Benchmarks* will be discussed in other Project 2061 materials. Although *Benchmarks* includes some commentary on aspects of instruction, that commentary is intended to clarify the meaning and intent of specific *Benchmarks*, not to present a systematic and detailed program of instruction.

■ ***Benchmarks* is informed by research.** Research on students' understanding and learning bears significantly on the selection and grade placement of the *Benchmarks*. Project 2061 surveyed the relevant research literature in the English language (and some in other languages) in search of solid findings on which to base benchmark decisions. The findings are discussed in *Benchmarks*' Chapter 15, The Research . ase.

■ ***Bench. rks* is a companion for *SFAA*, not a subs .tute.** *SFAA* presents a vision of science-literacy goals for all students to reach by the time they finish the 12th grade, and *Benchmarks* maps out the territory that students must traverse to get there. *SFAA* emphasizes cogency and connectedness. *Benchmarks* emphasizes analysis of the *SFAA* story into components and their sequence. In grades 9–12, where building coherence and connections becomes the main task, no list of components would be adequate to represent science literacy. (Indeed, not all of the detailed ideas in *SFAA* are represented in *Benchmarks*.) At the 9–12 level, therefore, reference to *SFAA* is necessary more than ever for a complete picture of science literacy, which the 9–12 *Benchmarks* only approximate. So, when working with *Benchmarks*, be sure to have a copy of *SFAA* at hand.

As others use *Benchmarks* to shape local curriculum design, Project 2061 is using it as a guide in developing other resources.

The benchmarks represent learning thresholds that all students are expected to reach on the way to becoming science literate. They are carefully sequenced to ensure that difficult benchmarks for later grades are anticipated by early grade, precursor benchmarks that contribute to the later concept. Here, for example, are sample benchmarks from *Benchmarks for Science Literacy* that illustrate the K–12 progression of ideas for the topic Interdependence of Life:

Kindergarten through Grade 2

By the end of the 2nd grade, students should know that:

■ Animals eat plants or other animals for food and may also use plants (or even other animals) for shelter and nesting.

■ Living things are found almost everywhere in the world. There are somewhat different kinds in different places.

Grades 3 through 5

By the end of the 5th grade, students should know that:

■ For any particular environment, some kinds of plants and animals survive well, some survive less well, and some cannot survive at all.

■ Insects and various other organisms depend on dead plant and animal material for food.

■ Organisms interact with one another in various ways besides providing food. Many plants depend on animals for carrying their pollen to other plants or for dispersing their seeds.

■ Changes in an organism's habitat are sometimes beneficial to it and sometimes harmful.

■ Most microorganisms do not cause disease. and many are beneficial.

Grades 6 through 8

By the end of the 8th grade, students should know that:

■ In all environments—freshwater, marine, forest, desert, grassland, mountain, and others—organisms with similar needs may compete with one another for resources, including food, space, water, air, and shelter. In any particular environment, the growth and survival of organisms depend on the physical conditions.

■ Two types of organisms may interact with one another in several ways: They may be in a producer/consumer, predatory/prey, or parasite/host relationship. Or one organism may scavenge or decompose another. Relationships may be competitive or mutually beneficial. Some species have become so adapted to each other that neither could survive without the other.

Grades 9 through 12

By the end of the 12th grade, students should know that:

■ Ecosystems can be reasonably stable over hundreds or thousands of years. As any population or organisms grows, it is held in check by one or more environmental factors: depletion of food or nesting sites, increased loss to increased numbers of predators, or parasites. If a disaster such as flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one.

■ Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution.

■ Human beings are part of the Earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.

In addition to the sequential K–12 connections among benchmarks are many cross-subject connections in keeping with Project 2061's emphasis on the interconnectedness of knowledge. To encourage curriculum designers to build important connections into units and materials, some of these connections are made explicit—through essays and a cross-reference feature—in *Benchmarks*. *Benchmarks* also offers a survey of the research informing the content and grade-level placement of benchmarks.

Benchmarks is a developing product. It will undergo periodic updates as more research on learning becomes available and as users of *Benchmarks* report their experiences.

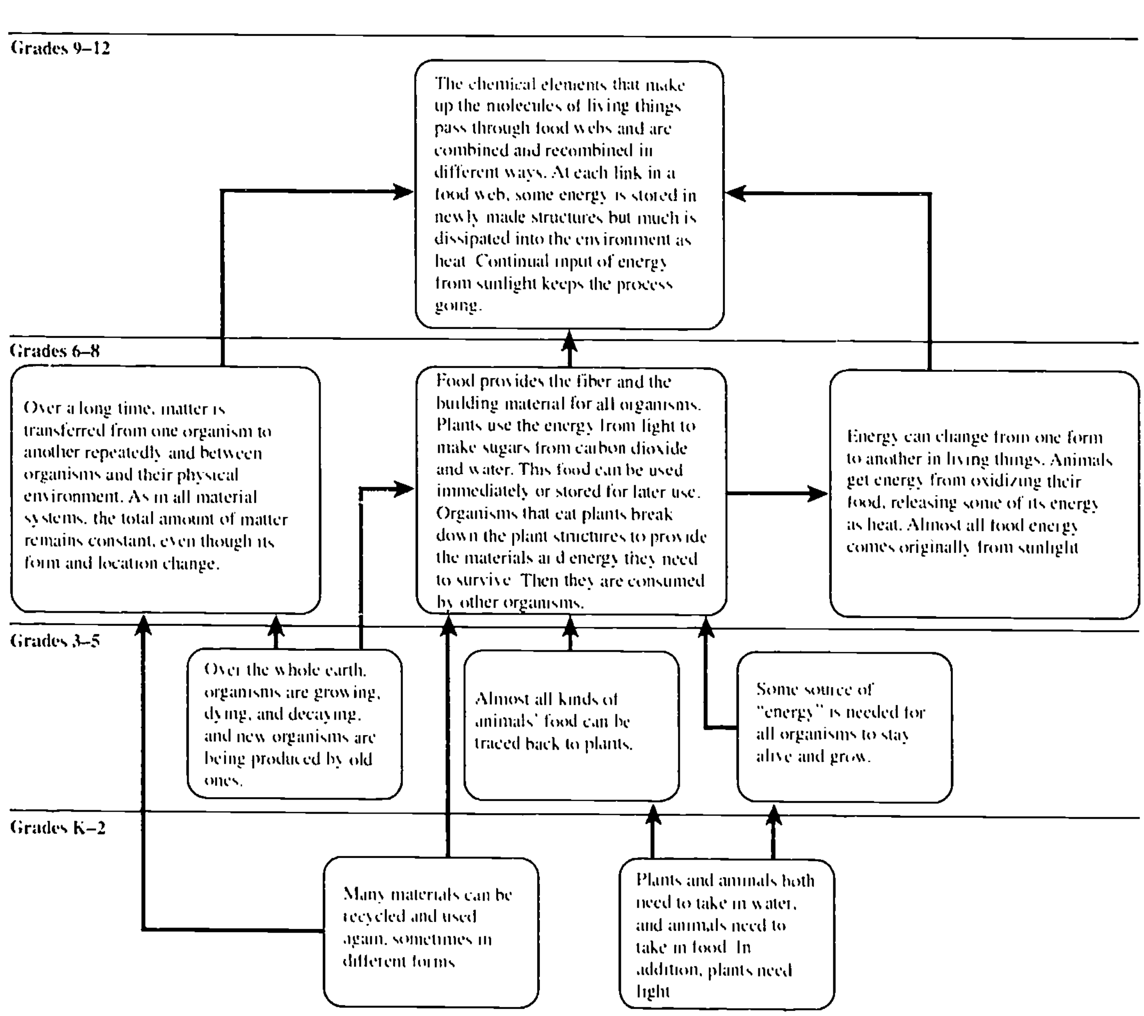
Benchmarks on Disk

The software version of *Benchmarks for Science Literacy* (available in MS-DOS, Macintosh, and Windows versions) is especially helpful in curriculum design in that it enables users to search for particular text words and to assemble and print sets of related benchmarks by grade level. Users can also browse through the entire *Benchmarks* text. A cross-reference feature allows users to quickly consult other sections of *Benchmarks* related to the benchmarks at hand and note important connections among the benchmarks across grade levels and across topics. Another feature provides the research base that influenced the content and grade-level placement of benchmarks.

Benchmarks on Disk contains several other features not available in the book. Users can access sample "strands," sequences of benchmarks that trace student progress toward particular 12th-grade science literacy goals, to see how concepts develop from rudimentary ideas suitable for young children to some of the sophisticated concepts in *Science for All Americans*. The DOS disk released in 1994 contains 20 sample strands; the new Mac and Windows versions offer 30. The strands cover a wide range of topics, including Centrality of Evidence, Feedback and Control in Technological Systems, Water Cycle, Conservation of Matter, Flow of Matter in Ecosystems, Fossil Evidence, Culture and Heredity Influence Behavior, World Markets, and Physical and Conceptual Models and Their Uses. Each strand is accompanied by a map that illustrates how the benchmarks build on and reinforce one another as they lead up to a specific learning goal from *SFAA*. The sample strands and maps can be used in the analysis and planning of a K–12 curriculum, or, we hope, can inspire users to develop additional strands for other goals in *SFAA*.

Benchmarks Roulette, another feature on the disk, provides users with a random sampling of six benchmarks from one grade span and challenges them to develop an activity that covers as many of the benchmarks as possible. The exercise can serve as a warm up for more deliberative attempts to look across the boundaries of traditional disciplines and assemble conceptually interesting sets of benchmarks for instruction and assessment.

Flow of Matter and Energy Partial Map



Project 2061 Today

With the widespread acceptance of the ideas in *SFAA*, as well as growing national interest in goal-directed reform in general and *Benchmarks* in particular, Project 2061 is currently developing additional reform tools to help school districts meet goals for science literacy. Three such tools, *Resources for Science Literacy*, *Blueprints for Reform*, and *Designs for Science Literacy* are in various stages of development. The school-district teams, now referred to as School-District Centers, continue their involvement in the Project's research and development, as well as in outreach efforts to help other educators understand and use the Project 2061 tools. Project 2061 also collaborates with other national and federal reform initiatives interested in promoting science literacy.

Reform Tools Under Development

Resources for Science Literacy

Educators will need a wide variety of materials to create curricula for science literacy. Since the publication of *Benchmarks for Science Literacy*, one of the most frequent requests the Project receives is for help identifying curriculum materials that support benchmarks. To help educators identify and thoughtfully analyze resources as they plan K–12 curricula around the learning goals in *SFAA* and *Benchmarks for Science Literacy*, Project 2061 is developing *Resources for Science Literacy*, a new two-part computer-based tool available for Mac and Windows. *Resources* will contain resources related to both professional development and curriculum materials.

Our work with teachers over the past 6 years has shown us that few have had the opportunity to gain strong backgrounds in science, mathematics, *and* technology or think of them as connected endeavors. *Resources for Science Literacy: Professional Development* will help teachers enhance their understanding of science literacy and guide them in making sound decisions about curriculum materials. This computer disk will contain descriptions of resources—science tradebooks, videos, software, articles, and university syllabi—that can improve teachers' understanding of science, mathematics, and technology, and their interconnections. Topics from *SFAA* and *Benchmarks for Science Literacy* with which teachers are least likely to be familiar—e.g., technology and the history of science—will be emphasized. The *Professional Development* disk will also offer advice and materials to help educators understand the carefully sequenced learning goals in *Benchmarks for Science Literacy*, indicating how they compare with the content goals in the National Research Council's *National Science Education Standards* (currently in draft form), the National Council of Teachers of Mathematics' *Curriculum and Evaluation Standards for School Mathematics*, and the National Council for the Social Studies' *Curriculum Standards for Social Studies*. Another important feature on the disk will be an introduction to cognitive research literature bearing on the ability of students of different ages to understand topics central to science literacy, including examples of curriculum design based on such research.

Over the past several years, our school-district teams of teachers worked with us to develop a prototype database of exceptional instructional materials. *Resources for Science Literacy: Curriculum Materials* will expand on this work to offer a database of curriculum resources—including descriptions of books, films, computerized resources, museum exhibits, and other materials—evaluated for overall quality and relevance to the learning goals in *Benchmarks for Science Literacy*. This disk will also explain how Project 2061 analyzes curriculum materials for their support of benchmarks, providing a tutorial to help educators who wish to carry out their own analyses. Information about assessment possibilities will also be available on the disk. Interactive utilities will enable educators to update their databases with additional resources they have analyzed, as well as to add commentary to existing items.

Resources for Science Literacy: Professional Development is designed for use in preservice education and inservice staff development programs, as well as for the professional growth of individual teachers. *Resources for Science Literacy: Curriculum Materials* will be useful to anyone, including teachers, engaged in curriculum planning or design.

Both *Resources for Science Literacy: Professional Development* and *Resources for Science Literacy: Curriculum Materials* will be expanded and revised based on user feedback, eventually to be merged into a single, CD-ROM version supported by annual updates available via disk or Internet.

Designs for Science Literacy

To move from goals to the design or redesign of an entire K–12 curriculum requires more than adding or subtracting some instructional units here and there or changing materials, tests, and techniques. What is needed is a coordinated K–12 plan that guides the curriculum-building process. *Designs for Science Literacy* will be a handbook for educators wanting to take a systematic, goal-oriented approach to curriculum design.

Designs will include:

- A discussion of the goals a Project 2061 curriculum should serve and the principles of learning and teaching on which a Project 2061 curriculum should be based.

- A systematic process for configuring K–12 curricula that meet Project 2061 standards and accommodate local and state policies, resources, and preferences.

- The requirements for and descriptions of curriculum blocks and models, samples of curriculum blocks suitable for a Project 2061 curriculum, and sketches of alternative K–12 curriculum models that illustrate a range of possibilities for curriculum design.

■ References to research that supports the recommendations in *Designs*.

Though meaningful, lasting reform requires a sustained effort, *Designs* will suggest how educators can see some immediate results as it provides direction for long-term, systemwide reform.

Blueprints for Reform

Curriculum reform by itself will not effect widespread or durable change. If lasting, meaningful reform is to occur, changes are needed throughout the education system. Hence, Project 2061 has convened expert groups to prepare a dozen concept papers on aspects of the education system that must change to accommodate the curriculum reforms being proposed by the Project. The findings of these papers will be presented in *Blueprints for Reform*, which will cover the following topics:

■ **Teacher Education** will identify changes needed in preservice and inservice teacher education to produce teachers with the knowledge and skills needed to implement curricula based on Project 2061 goals and principles.

■ **Materials and Technology** will identify what new resources are needed, what mechanisms to identify and access them will be effective, and what kinds of policies must be adopted to support the development and use of such resources.

■ **Assessment** will specify what immediate and future assessment needs are demanded by Project 2061 curriculum-design principles—from in-class assessment during instruction to program evaluation by schools to monitoring education progress at state and national levels.

■ **Curriculum Connections** will identify important linkages among the natural and social sciences, mathematics, and technology, and also between them and the arts and humanities, and will suggest how such linkages can be fostered in the curriculum.

■ **School Organization** will suggest what alternatives for school organization will best enable Project 2061 curricula to work. This paper will discuss such issues as grade structure, teacher collaboration, control of curriculum materials and assessment, how time and space in school might be organized, and the school as a learning community.

■ **Equity** will recommend education equity policies to ensure that science literacy is attainable by *all* students. It will also contribute to other *Blueprint* papers and ensure that their recommendations accommodate equity concerns.

■ **Parents and Community** will specify what will be needed for parents and the community to understand Project 2061 reform recommendations and what kinds of commitment and effort from them are needed.

■ **Business and Industry** will examine such issues as preparing students to enter an increasingly technological workplace and marketplace, the role of science literacy in U.S. competitiveness, appropriate partnerships between business and education, and resources and leadership that local business can bring to science instruction.

■ **Higher Education** will address such issues as what changes are needed in admission requirements to accommodate changes in high school course structure and assessment methods, and how undergraduate education should build on *SFAA*—especially for college students who may become teachers.

■ **Policy** will examine the entire policy picture, including how policy has inhibited past reform initiatives, challenges posed by the current education system for the implementation of Project 2061 reform, changes that may be needed in laws and regulations that govern schools, and how modifications of current policy might be achieved.

■ **Finance** will consider the implications of Project 2061 reform recommendations (including those in the other *Blueprint* papers) for the allocation of money and other resources. It will examine both the financial base for education and the potential availability of resources for changes needed to implement reform.

■ **Research** will discuss the research questions that arise in other *Blueprint* papers, *Benchmarks for Science Literacy*, and *Designs for Science Literacy*, as well as in initial attempts to implement Project 2061 reform. In addition, this paper will consider what mechanisms can permanently link research with practice.

The publication of *Blueprints for Reform* in 1997 will be timely: many states and an increasing number of urban and rural school districts are now undertaking systemic reform, which was not true when Project 2061 began. Project 2061 expects that *Blueprints for Reform* will contribute greatly to the effectiveness of those efforts and help educators overcome obstacles to curriculum reform.

Update on School-District Centers

Initially, we referred to school-district site teams. However, because the teams operate not as demonstration sites, but as research and development centers, we now refer to them as School-District Centers. The expanding teams at each of the five Centers remaining with the Project plan to use the Project design tools in developing and implementing curriculum. They also continue to contribute to the national Project 2061 endeavor. Currently, each of the Project 2061 School-District Centers divides its time between pursuing research and development activities for Project 2061, fostering reform in their individual school systems, and expanding the cadre of local educators informed about Project 2061 reform. The focus of their research and development varies: some Centers have been working on the systematic analysis of curriculum resources for evidence of their support of *Benchmarks* and their usefulness in developing curriculum blocks; others have begun to study assessment techniques suited to new curriculum resources, to work with higher education institutions to create teacher education programs based on Project 2061 tools and resources, and to develop curriculum blocks and models based on Project 2061 principles and literacy goals.

In general, the work of the Centers is becoming more closely tied to the use of Project 2061 tools and the development and identification of resources for classroom implementation. For the past several years, each School-District Center has established its own work agenda and drawn upon the talents of both Center participants and teachers newly affiliated with the Center to study *Benchmarks for Science Literacy* and to use it in the development and/or refinement of draft curriculum blocks for the Center's local curriculum models. Their attempts to develop curriculum resources to fill out their models exposed some of the strengths and weaknesses of the models as cohesive frameworks for promoting the goals in *SFAA* and *Benchmarks*. For some Centers, this led to major revisions of their models. Because they want to share their work with other school districts, the Centers are also dealing with questions about how their models can communicate clearly and succinctly a K–12 framework that covers all of the benchmarks. Their continued work on designing and implementing local models will provide helpful information to the Project as work progresses on *Designs for Science Literacy* and *Blueprints for Reform.*

Because of their work, Center participants are conversant not only with the thinking that went into developing *Benchmarks*, but also with ways in which *Benchmarks* can inspire educators to rethink their approaches to curriculum, instruction, and assessment. All of the Centers are working on the identification of curriculum resources that foster understanding of the learning goals in *Benchmarks for Science Literacy*. Some of the Centers helped generate guidelines for the use of *Benchmarks for Science Literacy* in curriculum development, others have collected documentation on teacher reflections on the use of *SFAA* and *Benchmarks*, and still others have collected student reflections on learning experiences derived from specific *Benchmarks*.

Participants at each Center have long been ambassadors for Project 2061 and are increasingly involved in presenting professional development workshops to their colleagues on the use of Project 2061 curriculum-design tools.

Center participants are also forming ties with other national, state, and local initiatives. They fulfill this role in a variety of ways—serving on boards and advisory councils for other initiatives, making presentations to other reform efforts on Project 2061's vision for systemic reform, and working with state education agencies to shape development of curriculum frameworks around *Benchmarks for Science Literacy*.

Outreach

Project 2061 does not expect to reform the education system singlehandedly, and so contributes to and cooperates with education initiatives at the local, state, and national levels that are moving in our same general direction. Throughout the development of *Benchmarks*, the Project has supplied other organizations with samples of our work in progress and conscientiously solicited input from the science, mathematics, and technology education communities. By providing the National Research Council's (NRC's) National Committee on Science Education Standards and Assessment with copies of *SFAA* and drafts of *Benchmarks*, we were able to contribute to their thinking and help shape their emerging national standards.

In their most recent draft form (November 1994), the content goals in the *National Science Education Standards* are highly consistent with those of Project 2061. We will be cooperating with the National Research Council to ensure that educators and curriculum developers understand how *Benchmarks for Science Literacy* and the *Standards* complement one another and represent a strong consensus on what is important in science. We are also working closely with federal programs, such as the National Science Foundation's Statewide, Urban, and Rural Systemic Initiatives, and national organizations, such as the National Science Teachers Association, to help them make effective use of Project 2061 reform tools.

The reform tools being developed by Project 2061 are having a more rapid impact than originally expected because they directly serve local and State reform initiatives. For instance, even before its publication, successive drafts of *Benchmarks* were used by States and school districts to guide their framework efforts. To help determine the full impact on science education of Project 2061's *Science for All Americans* and *Benchmarks for Science Literacy*, a third-party evaluator will be engaged to conduct an in-depth assessment of the Project's influence and effectiveness. The findings of this study will help the Project respond to the needs of the education community and develop tools and strategies that will move science education reform forward. As educators, scientists, and the general public become aware of the existence and usefulness of Project 2061 reform tools, and as leaders call for their use, prospective users require help in learning how to work with unfamiliar materials and processes. Because we are interested in doing much more than just distributing our products, we are engaged in extensive outreach efforts to ensure that educators at the school-district level understand the Project reform tools and how to put them to work in their own districts.

Many educators using *Benchmarks* to redo their curriculum frameworks, plan local curricula, or even to enhance their classroom teaching have contacted us, requesting guidance from the Project about how to use *Benchmarks* most effectively. Project staff responded to these requests by developing a *Benchmarks* workshop. The basic workshop for teachers and administrators includes an introduction to Project 2061, discussion of key features of the *Benchmarks* book, exercises in using the book to evaluate resources and curriculum activities, and a discussion of *Benchmarks on Disk* and other Project 2061 technology. Because we believe that good curriculum planning requires thoughtful discussion and collaboration among individuals from different disciplines and grade levels, the workshop is designed to allow participants to share insights from their various professional standpoints as they work together on tasks that reveal important features of *Benchmarks*.

To meet the many requests for *Benchmarks* workshops, about 35 individuals conversant with Project 2061 and experienced in giving presentations worked closely with Project staff to develop and try out the workshop with various audiences. These individuals are now delivering *Benchmarks* workshops across the country as occasion demands. The workshop has been offered to groups as diverse as 150 K–12 teachers from the Washington, D.C., school system, groups convened by the Project 2061 School-District Centers, materials developers, state science supervisors, teachers at the National Science Teachers Association regional and national meetings, and nine groups of educators throughout Iowa who were reached simultaneously via the state's fiber-optic network. Groups wishing to sponsor a workshop should contact the Project for more information.

Finally, the Project 2061 newsletter, *2061 Today*, keeps its 50,000-plus recipients informed of our latest thinking and products. It can be requested from our office (see p. 30).

Plans for the Future

Project 2061 will continue to develop reform tools and offer guidance to educators engaged in reforming K–12 education. We foresee undertaking a number of interrelated tasks over the next several years, all of which are driven by our vision of what education in science, mathematics, and technology should look like in the 21st century.

The Project 2061 Agenda

We plan to have *Resources for Science Literacy*, *Blueprints for Reform*, and *Designs for Science Literacy* completed, field tested, and in use over the next several years. As with *SFAA* and *Benchmarks for Science Literacy*, these tools will be revised periodically based on evidence from users about their effectiveness. Eventually, the two *Resources for Science Literacy* disks will be merged in a computerized curriculum design system. The system, available through CD-ROM or online through Internet, will incorporate all of the Project's tools and resource information to support educators and other users in the analysis, construction, and management of curricula for science literacy. The School-District Centers will continue to contribute to the Project's research and development as they attempt to implement aspects of Project 2061 reform in their own districts.

To encourage the effective use of *Science for All*

Americans, *Benchmarks for Science Literacy*, and the rest of the Project 2061 reform tools, we will continue to offer briefings, presentations, and workshops to educators, policymakers, and agencies and organizations engaged in reforming science, mathematics, and technology education. In addition, as *Blueprints for Science Literacy* is prepared for publication, the Project will host a series of conferences to consider the recommendations in the preliminary blueprint reports. These conferences should engage many groups involved in education—teachers, university faculty, policy makers, and community leaders, to name a few—in focused discussion of science literacy and related reform issues. These discussions should also help groups already engaged in reform to identify ways and means to increase the magnitude and effectiveness of the reform movement. The Project intends to offer another series of conferences for publishers, film producers, software developers, test makers, and other appropriate organizations to encourage the development of learning, teaching, and assessment materials that focus on science literacy. As new Project 2061 products appear, workshops and summer institutes will be put in place to offer training in the use and understanding of the reform tools.

Project 2061 will continue to press for nationwide acceptance of the goals and philosophies of SFAA and *Benchmarks for Science Literacy*, and to form alliances with teachers and other reformers ready to work with us toward mutual goals.

The Project 2061 Vision: Towards Science Literacy

What is the Project 2061 vision for science, mathematics, and technology education in the 21st century? What will we have to see in the schools to know that our reform efforts were successful?

■ First, a common core of learning in science, mathematics, and technology will focus on science literacy as its main goal and be closely allied with a common core of learning in the arts and humanities. Instructional units will be based on the explicit, grade-appropriate learning goals in *Benchmarks for Science Literacy*—expectations for what adults should retain. A comparison of this new core curriculum with the traditional curriculum of today would show far fewer topics than before, so that students can concentrate on learning well a basic set of ideas and skills that will lead to science literacy—and optimally promote further learning. Equally important, the curriculum will provide ample opportunity for students to go beyond the core in response to their individual interests, talents, and plans for the future.

■ Second, all students in a Project 2061 school will have wide-ranging learning experiences. Instructional units will employ a variety of instructional methods—projects, seminars, independent study, individual and cooperative work, and even traditional, didactic teaching. Each will have a place. Students will have many opportunities for hands-on activities and, equally important, for the reflective thinking that enables them to make sense of their experiences—including connecting ideas among science, mathematics, and technology, and between them and the arts and humanities. Students' activities and reflections will engage them in using their knowledge in ways characteristic of literate adults—to explain everyday phenomena, to solve practical problems, to inform decisions about issues, and thereby to learn more and have more personal satisfaction. Learning materials will vary, and less reliance on textbooks and more on computers and technology will be possible.

■ Third, teachers will have primary responsibility for planning and implementing curriculum within their individual systems. K–12 teams will plan for K–12 continuity of experiences, and cross-discipline groups will plan for how students will encounter connections within the curriculum. Curriculum designers will not have to develop a curriculum from scratch but will be able to select from a wide variety of instructional units that foster *SFAA* goals while matching the needs of the local community. Furthermore, the teams that formulated the curriculum will monitor and coordinate its operation.

■ Fourth, the school environment will support the science-literacy goals and the curriculum designed to achieve them. The scheduling of time and personnel will be suited to the demands of the learning experience. Schools will welcome information and participation from outsiders who can contribute to the specified learning goals. Students and teachers will be able to leave school grounds to participate in activities in the community or to learn science in the field rather than in the school. Resources will be readily available for teachers and administrators to learn about new research findings and their implications for practice and to engage in similar study themselves.

- And finally, everyone, including parents, policymakers, and teachers, will understand that reform is a continuing process, requiring time and consistent effort. We are not looking to see all-out reform culminate in general complacency with the transformed education system. If Project 2061 is successful, questions about the way education works in this country, enthusiasm for universal science literacy, and research and development aimed at new approaches and materials will continue.

Getting Started

Who should use Project 2061 tools, and how? Everyone engaged in state or local efforts to reform science, mathematics, and technology education should find the Project tools helpful. The following suggestions for using Project tools came from Project 2061 team members, consultants, staff, and individuals who have been using *SFAA* and *Benchmarks* in various ways.

■ Study groups of teachers, administrators, school-board members, parents, interested citizens, and, whenever possible, scientists, engineers, and mathematicians, can use *SFAA* and *Benchmarks* to explore the concept of science literacy and its implications for instruction in the early elementary, upper elementary, middle, and high school grades.

■ Cross-grade, cross-subject committees of teachers and curriculum specialists can use *Benchmarks* and *SFAA* to gauge how well a specific K–12 curriculum or curriculum framework (state or local) promotes science literacy.

■ School districts can consult the clear goals and flexible guidelines in *Benchmarks* and *Science for All Americans* to come up with the best and most effective ways of promoting science literacy among their students. *Resources for Science Literacy* and, eventually, the CDR System, will help local curriculum designers, including teachers, to draw on current research and the best available resources to decide what will go on in their classrooms.

■ Developers of instructional materials can use

Benchmarks and *SFAA* to guide the creation of materials to support the work of teachers who are trying to foster science literacy for all students. Similarly, test writers can use *Benchmarks* to develop grade-level materials and techniques for assessing student progress toward science literacy.

■ Other reform efforts may find *Benchmarks* useful in supporting their work, just as Project 2061 has relied on so many of them for ideas and information. The federal programs that drew heavily on *SFAA*, such as the Statewide Systemic Initiatives (National Science Foundation), the Eisenhower Science and Mathematics Initiative (U.S. Department of Education), and the National Assessment of Educational Progress, have indicated that they also intend to use *Benchmarks*. The *National Science Education Standards* (NRC) acknowledges extensive use of *SFAA* and *Benchmarks*.

■ Universities and colleges that prepare elementary and secondary school teachers can use both *SFAA* to explore the concept of science literacy and *Benchmarks* to raise issues closer to the realities of curriculum and instruction.

■ Researchers can refer to Project tools to identify important topics for investigation. Such topics might include studies on the grade-level placement of *Benchmarks*, the relationship between *Benchmarks* and their precursors, effective ways to group *Benchmarks* into instruction units, how to assess student progress toward science literacy, and how to evaluate learning materials and techniques used in support of the *Benchmarks*.

For Further Help

If you would like more information on Project 2061 or would like to receive our newsletter, please contact us at:

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Washington, DC 20005
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E-Mail: project 2061@aaas.org
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Science for All Americans, Benchmarks for Science Literacy, and *Benchmarks on Disk* are published by Oxford University Press. They can be ordered by mail or telephone from:

Oxford University Press
200 Madison Avenue
New York, NY 10016
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The Project 2061 Panel Reports (Biological and Health Sciences, Mathematics, Physical & Information Sciences and Engineering, Social and Behavioral Sciences, and Technology) are available from:

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The Eisenhower National Clearinghouse for Mathematics and Science Education

The Eisenhower National Clearinghouse for Mathematics and Science Education (ENC) is funded through the U. S. Department of Education to provide K–12 teachers with a central source of information on mathematics and science curriculum materials. ENC was established in 1992 through a contract with The Ohio State University and is located in Columbus, Ohio.

ENC encourages the adoption and use of K–12 curriculum materials and programs that support state and national efforts to improve teaching and learning in mathematics and science. It provides better access to resources by creating, maintaining, and cataloging a comprehensive, multimedia collection of materials and programs. The ENC catalog and other products are distributed nationally using both traditional formats and advanced computing and telecommunications technologies. Specifically, ENC provides the following products and services:

■ ENC's Resource Finder is a catalog of mathematics and science curriculum materials from Federal government agencies and many other sources. The cataloged materials include print; other media (including video, audio, graphic images, and software); kits; and online electronic resources. Catalog entries include a wealth of information, such as an abstract, cost of the item, and information on availability. The catalog database is available online via Internet and a toll-free number and, beginning in 1996, on CD-ROM.

■ By accessing ENC Online, users can readily obtain a variety of Internet resources, including a database of Federal programs serving mathematics and science education, the ENC catalog of curriculum materials, resources from other education databases, and information and materials on education reform, including this publication.

■ A repository of curriculum materials is located in Columbus, Ohio, for educators and others to examine the complete ENC collection and a smaller repository, the Capital Collection & Demonstration Site, in Washington, D.C., at The George Washington University.

■ To answer questions concerning curriculum resources, ENC has a reference service; also there is a technical help desk to answer questions about online access available through the toll-free telephone number.

■ ENC offers a variety of print materials, including topical catalogs on selected materials in the collection, information about Federal programs serving mathematics and science education, informational materials about ENC, and materials about reform in mathematics and science education.

■ There are twelve demonstration sites, located in conjunction with the 10 Eisenhower Regional Consortia, at The Capital Collection & Demonstration Site, and at ENC. Demonstration sites provide an opportunity for users to preview the ENC Online Information Service as well as a variety of software and other materials.

■ Beginning in 1996, two CD-ROM collections will be produced per year. The first collection will include materials that support education reform, such as curriculum frameworks and information on standards, assessment, and professional development, and the second will make print and software curriculum materials available for classroom use. Each disk will also include the complete ENC catalog and an Internet directory that can be used to demonstrate the benefits of Internet access.

Access to ENC Online Services

The ENC online information service includes the electronic catalog of mathematics and science curriculum materials and a set of Internet resources for K–12 teachers. With a computer and a modem or Internet access, anyone can use ENC Online.

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With an Internet connection, use the telnet command to connect to **enc.org** and login as **guest**. It is also possible to connect to ENC at **http://www.enc.org** using World Wide Web software. If connecting through the World Wide Web, a login is not necessary.

Modem:
With a modem, dial **(800) 362-4448** for toll-free access. (Although not a toll-free call, (614) 292-9040 also provides access.)
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Monograph #2

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